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**TITLE:**

**FLAT PLATE HEAT EXCHANGER COIL AND METHOD OF OPERATING THE  
SAME**

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# FLAT PLATE HEAT EXCHANGER COIL AND METHOD OF OPERATING THE SAME

## BACKGROUND OF THE INVENTION

### Field of the Invention

[001] The present invention relates generally to coils for use in heat exchangers. More particularly, relating to flat plate coils used in bulk material type heat exchangers.

### Description of the Prior Art

[002] Typically, in processing bulk materials, such as pellets, granules, powders or the like, heat exchangers are employed to either cool or heat the material during the processing thereof. The heat exchangers employed consist of an array of plate-like coils arranged side-by-side in spaced relationship and are positioned in an open top and open bottom housing. The like ends of each coil are connected to together by means of a manifold and a heat exchange medium, such as water, oil, glycol or the like is caused to flow through the coils. Generally, the material treated by the heat exchanger is allowed to gravity flow through the housing and the spaces between the spaced plate coils. During the progression of the material through the heat exchanger, the material is caused to contact the walls of the plate coils thereby effecting heat transfer between the material and the plate coils. The rate at which the material flows through the heat exchanger and ultimately across the plate coils can be controlled by restricting the flow of the material at the outlet of the heat exchanger..

[003] The plate coils are constructed by attaching metal sheets together along the edges thereof and this is normally accomplished by seam welding the sheets together to form a fluid tight hollow plate. Heretofore, plate coils have been constructed to operate

under internal pressure caused by pumping the heat exchange medium through the coil. To resist internal pressure and to prevent the sides of the coils from deforming, depressions or dimples are formed along the plate coil. An example of similar plate coils and their use are described in U.S. Patent 6,328,099 to Hilt et al. and U.S. Patent 6,460,614 to Hamert et al.

**[004]** During the normal operation of the heat exchanger the bulk material tends to accumulate within the dimples or spot welds and continues to collect to a point where the efficiency of the heat exchanger is greatly reduced and must be cleaned to remove the material residue from the dimples and surrounding exterior surface of the coils. In some circumstances, the material is allowed to collect to a point where the material will bridge between adjacent plate coils; this not only reduces the heat transfer efficiency of the heat exchanger, but also restricts the flow of the material through the heat exchanger. These circumstances are very undesirable because the operation of heat exchanger must be shut down for a period of time to clean the coils, which many times means the material production line is also shut down, resulting in loss of production and ultimately loss in profits.

**[005]** Therefore, a need exists for a new and improved flat plate coil that can be used for bulk material heat exchangers which reduces the tendency for the material to accumulate on the coils. In this regard, the present invention substantially fulfills this need. In this respect, the flat plate coil according to the present invention substantially departs from the conventional concepts and designs of the prior art, and in doing so provides an apparatus primarily developed for the purpose of increasing the efficiency of bulk material heat exchangers and reducing down time thereof.

## SUMMARY OF THE INVENTION

[006] In accordance with the present invention, a flat plate heat exchanger coil for use in bulk material heat exchangers is provided. The flat plate coil comprises a plurality of sheets secured together along the edges thereof to form a fluid tight and hollow plate coil that is generally rectangular in shape. The sides of the plate coil are substantially smooth and free of depressions, indentations, ridges or the like. The flat plate coil includes an internal fluid flow passage defined by a plurality of flow diverters, which are positioned within the hollow space of the plate coil. Heat exchange medium is directed into an inlet nozzle formed in the plate coil and out of a similarly designed exit nozzle formed in the plate coil. Unlike conventional plate coils, the coil of the present invention is designed to operate under a negative internal pressure opposed to a positive internal pressure. Because the plate coil is designed to operate under a negative internal pressure the dimples or otherwise depressions formed on the exterior surfaces of prior art plate coils to withstand internal positive pressure loading are eliminated. In doing so accumulation of material on the exterior surface of the plate coil is reduced to a very minimal amount.

[007] To withstand the negative pressure within the plate coils, pressure-resisting elements are positioned within the plate coil and may be unattached or secured to either or both internal surfaces of the sidewalls of the coil. The pressure resisting members or pressure resistor members prevent the sidewalls of the plate coil from deforming or collapsing inward due to the negative operating pressure present within the plate coil.

[008] During initial filling of the plate coils with a heat exchange medium or during non-operational periods of the coils, the sides of the coil may tend to bow outward causing the coil to inflate due to the low positive pressure exerted by the heat exchange medium present within the coil in a static state. To prevent this from occurring, pressure

restraint members are positioned within the coil and are secured to both sides of the coil, thereby preventing the interior distance between the sides of the coils from increasing.

**[009]** Flow diverters are positioned within the flow passage of the plate coil and create flow channels for the heat exchange medium to follow. The flow diverters can be formed to any suitable shape from flat stock material or from solid or hollow sectional material and in some applications plastic mouldings could be employed. In addition, the flow diverters can also aid the pressure resistors in preventing the plate coil from collapsing due to internal negative pressures.

**[0010]** An additional advantage of operating the plate coil under negative pressure is the ability to use manifolds that are less expensive and less heavy duty than that of the manifolds required for plate coils that operate under positive pressure. A lighter duty and less costly manifold, typically a section of pipe or any hollow section material can be used.

**[0011]** In additional embodiments of the plate coil of the present invention, the coils are constructed with tapered sides, which is beneficial in the flow of fine particulate material. The increasing width of the material flow path due to the tapered design of the plate coil will reduce pressure build-up in the material, thereby making it less likely for particles to accumulate on the sides of the plate coils.

**[0012]** There has thus been outlined, rather broadly, the more important features of the invention in order that the detailed description thereof that follows may be better understood and in order that the present contribution to the art may be better appreciated.

**[0013]** Numerous objects, features and advantages of the present invention will be readily apparent to those of ordinary skill in the art upon a reading of the following detailed

description of presently preferred, but nonetheless illustrative, embodiments of the present invention when taken in conjunction with the accompanying drawings. In this respect, before explaining the current embodiment of the invention in detail, it is to be understood that the invention is not limited in its application to the details of construction, the materials of construction or to the arrangements of the components set forth in the following description or illustrated in the drawings. The invention is capable of other embodiments and of being practiced and carried out in various ways. Also, it is to be understood that the phraseology and terminology employed herein are for the purpose of descriptions and should not be regarded as limiting.

**[0014]** As such, those skilled in the art will appreciate that the conception, upon which this disclosure is based, may readily be utilized as a basis for the designing of other structures, methods and systems for carrying out the several purposes of the present invention. It is important, therefore, that the claims be regarded as including such equivalent constructions insofar as they do not depart from the spirit and scope of the present invention.

**[0015]** For a better understanding of the invention, its operating advantages and the specific objects attained by its uses, reference should be had to the accompanying drawings and descriptive matter in which there is illustrated preferred embodiments of the invention.

#### BRIEF DESCRIPTION OF THE DRAWINGS

**[0016]** The invention will be better understood and objects other than those set forth above will become apparent when consideration is given to the following detailed description thereof. Such description makes reference to the annexed drawings wherein:

**[0017]** Figure 1 is a side elevation view of an embodiment of flat plate coil of the present invention.

**[0018]** Figure 2 is an isometric view of the preferred embodiment of the bulk material heat exchanger constructed in accordance with the principles of the present invention in use with the flat plate coils of the present invention.

**[0019]** Figure 3a is a cross sectional view of an end of an embodiment of the flat plate coil of the present invention illustrating one possible method of adjoining the sheets of the coil.

**[0020]** Figure 3b is a cross sectional view of an end of an embodiment of the flat plate coil of the present invention illustrating a second possible method of adjoining the sheets of the coil.

**[0021]** Figure 3c is a cross sectional view of an end of an embodiment of the flat plate coil of the present invention illustrating a third possible method of adjoining the sheets of the coil.

**[0022]** Figure 3d is a cross sectional view of an end of an embodiment of the flat plate coil of the present invention illustrating a fourth possible method of adjoining the sheets of the coil.

**[0023]** Figure 3e is a cross sectional view of an end of an embodiment of the flat plate coil of the present invention illustrating a fifth possible method of adjoining the sheets of the coil.

**[0024]** Figure 4 illustrates a pressure resistor and a possible attachment method thereof to the flat plate coil of the present invention.

- [0025] Figure 5a illustrates a pressure restraint member and a possible attachment method thereof to the flat plate coil of the present invention.
- [0026] Figure 5b illustrates a pressure restraint member and a possible alternate attachment method thereof to the flat plate coil of the present invention.
- [0027] Figure 5c illustrates an alternate pressure resistor attached to a single side of the flat plate coil of the present invention.
- [0028] Figure 5d illustrates the pressure resistor of Fig. 5c and a possible arrangement method thereof to the flat plate coil of the present invention.
- [0029] Figure 5e illustrates the pressure resistor of Fig. 5c used as a pressure restraint member and a possible attachment method thereof to the flat plate coil of the present invention.
- [0030] Figure 6a is a cross sectional view taken across a flow diverter of the coil in Figure 1.
- [0031] Figure 6b is a cross sectional view taken across an alternate flow diverter of the coil in Figure 1.
- [0032] Figure 6c is a cross sectional view taken across an alternate flow diverter of the coil in Figure 11, discussed below.
- [0033] Figure 7 is a side elevation view of an alternate embodiment of the flat plate coil of the present invention.

**[0034]** Figure 8a is a cross sectional view taken through a flow diverter of the coil in Figure 7.

**[0035]** Figure 8b illustrates an alternate embodiment of Figure 8a.

**[0036]** Figure 9 is a side elevation view of the tapered embodiment of the flat plate coil of the present invention.

**[0037]** Figure 10a is a cross sectional view of the coil in Figure 9.

**[0038]** Figure 10b illustrates an alternate embodiment of Figure 10a.

**[0039]** Figure 11 is a side elevation view of an alternate embodiment of the flat plate coil of the present invention.

**[0040]** Figure 12 is a front elevation view of the flat plate coil of Figure 11.

**[0041]** Figure 13a is an isometric view of an alternate embodiment of a combined flow diverter and pressure resistor of the present invention.

**[0042]** Figure 13b is a front elevation view of an alternate embodiment of the flat plate coil of the present invention.

**[0043]** Figure 13c is an isometric view of an alternate combined flow diverter and pressure resistor of the coil in Figure 13b.

**[0044]** Figure 14 is a front elevation view of an alternate embodiment of the flat plate coil of the present invention.

- [0045]            Figure 15 is a cross sectional view of the coil in Figure 14.
- [0046]            Figure 16 illustrates the method of incorporating a removable seal between adjacent flat plate coils.
- [0047]            Figure 17 is a side elevation view of an embodiment of the flat plate heat exchanger coil of the present invention illustrating the typical placement of support holes for supporting the plate coil.
- [0048]            Figure 18 is a cross sectional view of one support hole of FIG. 17.
- [0049]            Figure 19 is a side elevation view of an embodiment of the flat plate heat exchanger coil of the present invention illustrating a typical placement of location lugs, indents, support lugs and lifting lug for the plate coil.
- [0050]            Figures 20a and 20b illustrate a method of automated cleaning of the flat plate coils of the present invention.
- [0051]            Figures 21a, 21b and 21c illustrate an alternate method of automated cleaning of the flat plate coils of the present invention.
- [0052]            Figure 22a illustrates an additional alternate method of automated cleaning of the flat plate coils of the present invention, where a plurality of cam elements are positioned along the length of a support bar.
- [0053]            Figure 22b illustrates one possible cam arrangement for use in the method of automated cleaning of the flat plate coils illustrated in Figure 22a.

[0054] Figure 22c illustrates a second one possible cam arrangement for use in the method of automated cleaning of the flat plate coils illustrated in Figure 22a.

[0055] Figure 23 illustrates an example of a cam arrangement to provide horizontal, back and forth movement of the plate coils.

[0056] Figure 24 illustrates an example of a cam arrangement to provide horizontal side-to-side movement of the plate coils.

[0057] The same reference numerals refer to the same parts throughout the various figures.

#### DETAILED DESCRIPTION OF THE INVENTION

[0058] Referring now to the drawings, and particularly to FIGS. 1-2, a preferred embodiment of the flat plate coil of the present invention is shown and generally designated by the reference numeral 10.

[0059] In Figures 1 and 2 a new and improved flat plate heat exchanger coil 10 of the present invention for the purpose of increasing the efficiency of bulk material heat exchangers and reducing down time thereof is illustrated and will be described. More particularly, in FIG.1, the flat plate heat exchanger coil 10 has a flat, generally rectangular metal body 12 having two opposing side sheets 14, two opposing longitudinal edges 16, and two opposing transverse edges 18. The two side sheets 14 are sealed to each other along the borders of the two longitudinal and two transverse edges 16 and 18 defining an open interior space. Figures 3a – 3d illustrate possible methods of seaming the edges of the flat plate heat exchanger coil 10. Heat exchange medium inlet and exit nozzles 20 and 22 are provided in fluid communication with the open interior space and can be arranged for example along a common longitudinal edge 16.

**[0060]** Each side sheet 14 is substantially smooth and free of depressions and/or dimples or the like. The phrase “substantially smooth” is to be defined in the context of this application for U.S. Letters Patent as free from ridges, depressions, and dimples or the like created in the sides of the flat plate heat exchanger coil during the manufacture thereof.

**[0061]** Prior art plate coils are manufactured with dimples and/or depressions formed on the sides thereof and welded together to increase the resistance of the sides from bowing outward due to a positive internal operating pressure created by pumping a heat exchange medium through the coil. These dimples are a drawback to prior art plate coils because in service bulk material tends to accumulate in these dimples which has a negative two fold effect. First, the heat transfer between the bulk material and the coil is reduced by a loss of effective surface area of the coil and second the bulk material may be allowed to accumulate to a point where the material bridges between adjacent coils thereby impeding the flow of the material through the heat exchanger. Once this occurs, the heat exchanger must be removed from service and cleaned, which results in undesirable down time of the material production line. To overcome the drawbacks of the prior art, the flat plate heat exchanger coil 10 of the present invention is designed to operate under a negative internal pressure, thereby eliminating the need to create dimples on the sides of the coil.

**[0062]** Turning to Figure 2, numerous flat plate coils 10 are illustrated in an exemplary in-use arrangement positioned within a typical bulk material heat exchanger 24. The flat plate heat exchanger coils 10 are arranged side-by-side in a spaced relationship within the shell of the bulk material heat exchanger 24. The inlet nozzle 20 of each coil 10 is connected to a common heat exchange medium supply manifold 26 and the exit nozzle 22 of each coil is also connected to a common heat exchange medium return manifold 28. The inlet nozzle 20 and the exit nozzle 21 can be formed to any

suitable shape, such as but not limited to a rectangle or a circle. In operation, a vacuum source is provided at the heat exchange return manifold 28 and the flow of the heat exchange medium is indicated by arrows 30, where the heat exchange medium enters the supply manifold 26 and is distributed to each of the inlet nozzle 26 of each coil 10. The heat exchange medium is then drawn up and through each coil 10 and ultimately out of the heat exchange medium return manifold 28. Arrows 32 indicate the flow of the bulk material, and the material flows through the heat exchanger and across the coils 10, typically under the force of gravity. With this arrangement, the bulk material heat exchanger 24 operates as a counter flow type heat exchanger.

**[0063]** The coil 10 as indicated above, is designed to operate under a negative internal pressure or vacuum as low as about 10 psi (70kPa) on a vacuum gage. To prevent the side sheets 14 of the flat plate heat exchanger coil 10 from collapsing at least one pressure resistor member 34 is positioned and strategically arranged within the interior space of the coil. During non-operational periods of the coil 10, a positive internal pressure may be present due to the hydrostatic pressure of the heat exchange medium present within the coil in a static state. To prevent inflation or deforming of the sides of the coil 10, at least one pressure restraint member 36 can be included and is positioned and strategically arranged within the interior space of the coil.

**[0064]** At least one flow diverter 38 is positioned within the coil 10 to a create flow passage for the circulating heat exchange medium to flow through. Preferably, flow diverters 38 are arranged to create a serpentine-like flow path for the heat exchange medium. The flow diverters 38 can also aid the pressure resistor members 34 in preventing the sides of the coil 10 from collapsing.

**[0065]** Figure 4 illustrates a pressure resistor member 34 positioned between the interior surfaces 40 of the side sheets 14 of the coil 10. The pressure resistor member 34 is generally cylindrical and is attached at one end to one interior surface 40 of a single

side sheet 14. Preferably, the pressure resistor member 34 is attached at one end to the interior surface 40 by a weld 42 with the opposite end of the pressure resistor member free from attachment to the opposing interior surface of the other side sheet. In a preferred embodiment, the pressure resistor member 34 is of a length equal to the distance between the interior surfaces 40 of the coil side sheets 14. In the manufacture of the coil 10, a predetermined number and arrangement of pressure resistors 34 are first attached in a desired pattern to the interior surface 40 of the side sheets 14 before the side sheets are assembled with the coil 10.

**[0066]** Turning to Figure 5a, one possible embodiment of a pressure restraint member 36 is illustrated and will be described. The pressure restraint member 36 is attached at one end to one interior surface 40 of one side sheet 14 by weld 44. The opposite end of the pressure restraint member is plug welded 46 to the opposite side sheet 14 through a hole 48 formed therethrough and dressed flush with the exterior surface 54 of the side sheet. In this embodiment, the pressure restraint member 36 is cylindrical in shape and is of a length equal to the distance between the interior surfaces 40 of the side sheets 14.

**[0067]** Now turning to Figure 5b, an alternate embodiment of a pressure restraint member 36 is illustrated and will be described. The pressure restraint member 36 is attached at one end to one interior surface 40 of a side sheet 14 by a weld 44. In this embodiment, the pressure restraint member 36 is of a length to pass through a hole 50 formed through the opposite side sheet 14 and is welded 52 around the hole 50. In this application, the weld 52 and the end of the pressure restraint member are dressed flush with the exterior surface 54 of the side sheet 14.

**[0068]** Referring to Figures 5c-5e, an alternate embodiment of a pressure resistor member 34 and a pressure restraint member 36 is illustrated and will be described. The pressure resistor member 34 and the pressure restraint member 36 have a cylindrical

body, closed at one end 56 and a flanged end 58. Application of the pressure resistor member 34 is illustrated in Figure 5d, where the flanged end 58 is attached to the interior surface 40 of one side sheet 14 by a circular weld 60. The pressure resistors 34 can be attached to the interior surfaces 40 of the side sheets 14 in an alternating pattern as illustrated. Application of the pressure restraint member 36 is illustrated in 5e, where the flanged end 58 is attached to the interior surface 40 of one side sheet 14 by a circular weld 60. Then on assembly with the other side sheet 14, the cylindrical body 56 is weld thereto by weld 62. The pressure restraint member s 36 can be attached to the interior surfaces 40 of the side sheets in an alternating pattern as illustrated.

**[0069]** Turning now to Figure 6a, which is a cross sectional view of the flat plate heat exchanger coil 10 as illustrated in Figure 1. This figure shows an example of one possible form of a flow diverter 38 positioned within the plate coil 10 and between the side sheets 14. In this example, the flow diverter 38 is a strip of material having a bend of approximately 90 degrees along a centerline thereof. The flow diverter 38 includes a plurality of holes 64 formed therethrough along the centerline thereof. The holes 64 allow the flow diverter 38 to be positioned about an arrangement of pressure resistors 34 and/or pressure restraint members 36. Referring back to Figure 1, which illustrates the placement of multiple flow diverters 38 about the pressure resistors 34 and pressure restraint member s 36 to create a serpentine flow path for the heat exchange medium. The positioning of the flow diverters 38 as illustrated is for exemplary purposes only as the flow diverters can be arranged in any manner to create a desired flow path for the heat exchange medium.

**[0070]** Figure 6b illustrates an example of a combined flow diverter and pressure resistor 38 positioned within the plate coil 10 between the side sheets 14. In this example, the combined flow diverter and pressure restraint 38 is a strip of material having opposed edges bent orthogonal to the side sheets 14 to form two legs 15. These legs act as pressure resistors to prevent the collapse of the plate coil 10 when operated under a

negative pressure. The diagonal web 17 includes a plurality of locating holes 64, and creates to flow passages 19 for the heat exchange medium.

[0071] Figure 6c illustrates an additional example of a combined flow diverter and pressure resistor 38 in the form of a corrugated formed sheet of material positioned within the plate coil 10 and secured to the interior surfaces 40 of the side sheets 14.

[0072] Turning to Figures 7, 8a and 8b an alternate embodiment of the flat plate heat exchanger coil 10 and flow diverters 38 of the present invention is illustrated and now will be described. In this embodiment, the flow diverters 38 are formed from a solid rod or tube, which are bent and positioned within the coil 10 to create a desired heat exchange medium flow path. The pressure resistors 34 and the pressure restraint members 36 are strategically positioned and attached to the side sheets 14 of the coil 10 to aid in the correct placement of the formed flow diverters 38. Preferably, the pressure resistors 34 and restraints 36 are positioned to alternate from side to side of the flow diverters 38, as illustrated in Figure 7. Figure 8a is an enlarged partial cross section of the plate coil 10 illustrated in Figure 7 and this figure shows a flow diverter formed from a solid rod and illustrates the method of positioning the pressure resistors 34 and/or restraints 36 on opposite sides of the flow diverter 38 to aid in the positioning and retention thereof. Figure 8b illustrates an alternate embodiment of the flow diverter 38 illustrated in Figure 8a. In this embodiment, the flow diverter is a tube. The flow diverters 38 illustrated in Figures 7, 8a and 8b are of a material having a circular cross section for exemplary purposes only and should not limit the possibility of using material of other cross sectional shapes.

[0073] Referring now to Figures 9, 10a and 10b, which illustrate an additional embodiment of the flat plate heat exchanger coil 10 of the present invention. In this embodiment the thickness of the coil 10 decreases in the direction from one transverse edge to the second transverse edge. Preferably, the thickness of the coil 10 decreases in

the direction of the flow of bulk material across the coil. Preferably in this particular embodiment incremental steps 66 decrease the thickness of the coil 10. Most preferably, the steps 66 and thickness of the coil 10 correspond with the various diameters of rod or tube used for the flow diverters 38. Figure 9 also illustrates an additional possible arrangement of the flow diverters 38 to create a serpentine flow path for the heat exchange medium. As in all of the aforementioned embodiments of the flat plate coil 10, the flow diverters in this embodiment can aid the pressure resistors 34 in preventing the side sheets 14 of the coil 10 from collapsing. During the manufacture of this embodiment of the flat plate coil 10 the longitudinal edges 16 are cut to match the step profile of the side sheets 14 of the coil. Preferably, the longitudinal edges 16 are laser cut to match the step profile of the side sheets 14.

**[0074]** Figure 10a is a side elevation view illustrating an example of one method of creating a tapered flat plate coil 10. In this example, the side sheets 14 of the plate coil 10 are formed by overlapping sections of sheet metal 68, as illustrated, which are then welded together. The thicknesses of the flow diverters 38 are equal to the distance between the interior surfaces 40 of the side sheets 14 for each step 66 of the coil 10. For exemplary purposes only, the flow diverters in this figure are illustrated as solid rods.

**[0075]** Figure 10b illustrates a side elevation view illustrating an example of a second method of creating a tapered flat plate coil 10. In this example, a single sheet is used for each side sheet 14 and the sheet is bent inward at various positions along the length thereof to create the required stepped profile of the side sheet. The thicknesses of the flow diverters 38 are equal to the distance between the interior surfaces 40 of the side sheets 14 for each step 66 of the coil 10. For exemplary purposes only, the flow diverters in this figure are illustrated as tubes.

**[0076]** Referring now to Figures 11, 12 and 13, which illustrate a third embodiment of the flat plate heat exchanger coil 10 of the present invention and an

additional example of a flow diverter assembly 38 for use with a tapered or parallel plate coil. The flow diverter assembly 38 of this embodiment includes a plurality of tapered flow diverter strips 70 which are interlocked with a plurality of flow control strips 72. Preferably, the flow control strips 72 and the tapered flow diverter strips 70 are interlocked orthogonal to each other. The flow control strips 72 include a plurality of reduced sections 74, which are formed to be positioned between adjacent tapered flow diverter strips 70 and serve to control the amount of heat exchange medium that passes each flow control strip. The flow diverter 38 of this embodiment is also used to prevent the tapered coil 10 from collapsing under negative operating pressure. Pressure restraint members 36 (not illustrated) may also be used in the same manner as described previously to prevent inflation of the coil 10 and to help position the flow diverter 38 within the coil.

[0077] Referring to Figures 13b and 13c, which illustrate a fourth embodiment of the flat plate coil 10 of the present invention and an additional example of a plurality of flow diverters 38 for use with tapered or parallel flat plate coils. The flow diverter 38 of this example is a tapered or parallel strip of material formed in a serpentine shape and includes a heat exchange medium flow control leg 39. The flow control leg 39 restricts the flow of heat exchange medium into each chamber 41 to ensure an even flow rate of heat exchange medium within each chamber across the plate coil. The flow diverter 38 of this example is also used to prevent the plate coil 10 from collapsing under negative operating pressure. In addition to the flow diverters 38, pressure restraint members 36, not illustrated, can be used in the same manner as previously described to prevent inflation of the plate coil 10 and to aid in the positioning of the flow diverters 38 within the plate coil.

[0078] Turning to Figures 14 and 15 a fifth method of creating a tapered flat plate coil 10 is illustrated. The flat side sheets 14 are in parallel planes and increase in width in a direction from one transverse edge 18 of the coil 10 to second transverse edge 18 of the

coil. Preferably, the thickness of the coil 10 remains constant along the length of the coil.

The gradual increase in width of the coil 10 creates a greater volume between adjacent coils in a bulk material heat exchanger, which releases pressure build-up in particulate material flowing through the heat exchanger. The flow diverters 38 of this example are of an open channel material having a closed side 76 and an open side 78 that includes a pair of flanges 80. The plate coil 10 is constructed by first attaching a plurality of flow diverters 38 to the interior surface 40 of one side sheet 14 by welds 82. The plurality of flow diverters 38 are attached to the side sheet 14 in a desired pattern to create a flow path for the heat exchange medium. Then the second side sheet 14 is attached to the coil 10 and the flow diverters 38 by welds 84 from the exterior side of the second sidewall. Preferably, the welds are laser welded. This method of construction provides for the placement of the flow diverters 38 within the coil and allows the flow diverters to function as pressure resistors and restraints.

**[0079]** Now turning to Figure 16, a removable seal 86 may be positioned between adjacent plate coils 10 to retain the flow of material 88 therebetween. The seal may be removed to help facilitate the cleaning of the coils 10 or by adjusting the vertical angle of the seal to control the flow of material 88 between the coils.

**[0080]** Referring to Figures 17 and 18, which illustrate a typical placement of support holes 90 through the flat plate coil 10. The support holes 90, which may be of any desired shape, are formed through both side sheets 14. A tubular sleeve 91 is placed in the support holes 90 then welded to both side sheets 14 and then dressed flushed with the exterior surfaces of the side sheets. The support holes 90 are typically used in supporting the flat plate coil 10 within a heat exchanger.

**[0081]** Now turning to Figure 19, which illustrates the capability of incorporating the placement of location lugs 92, which extend from the ends of the coil 10, indents 94 formed into the ends of the coil, support lugs 96 extending from the edges of the body of

the coil and a lifting lug 98 extending from the top of the coil. Currently, plate heat exchangers are manufactured with supports below the plate coils which can impede the flow of bulk material and also increase the overall height of the heat. The incorporation of location lugs 92, indents 94, support lugs 96, or a lifting lugs 98 eliminates the need for the supports below the plate coils and improves the flow path for the bulk material. The overall height of the heat exchanger can be reduced correspondingly.

[0082] Referring to Figures 20a and 20b, an additional embodiment the flat plate coil 10 is illustrated and will be described. In this embodiment, the flat plate coils 10 are designed and manufactured such that upon removal of the negative operating pressure the plate coil sides 14 will slightly inflate due to a positive internal pressure created exerted by the heat exchange medium. Isolating the vacuum source and allowing the heat exchange medium to develop a desired hydrostatic pressure within the plate coils 10 can achieve the slight inflating of the plate coil sides 14. Upon reestablishing the negative operating pressure, the plate coil sides 14 return to a non-inflated position. Preferably, the hydrostatic pressure is allowed to reach a about 5 PSI (34 kPa) and is only applied for a short duration. The duration is at least 1 second. Preferably the duration is from about 1 to about 10 seconds and most preferably, the duration is about 5 seconds. An automated pulsing system 100 can be incorporated in the heat exchange medium system 102 to cause the inflation-deflation cycle of the flat plate coils 10 at a predetermined frequency.

[0083] Incorporating the above cyclic inflation of the flat plate coils 10 in, for example a bulk material heat exchanger would be beneficial in processing fine particulate materials which tend to bridge across narrow spaces such as the gaps between adjacent flat plate coils, which creates blockages in the flow of the material. By inflating the plate coil sides 14 by a small fraction of an inch the gap between adjacent plate coils decreases thus compressing any bulk material in the gap. On returning the plate coil sides 14 to the non-inflated position, the gap between adjacent plate coils increases to the normal operation gap and the compressed bulk material is dislodged from the sides. This system provides for the

automated, self-cleaning of flat plate coils 10, which reduces operating costs and service time of the flat plate coils.

[0084] In an additional embodiment of the flat plate coils a system of providing automated, self-cleaning flat plate coils 10 is illustrated in Figures 21a, 21b and 21c. In this embodiment, the self-cleaning system includes a lift means 106 for lifting the plate coils 10 to aid in the removal of any bulk material that has accumulated on the exterior surfaces of the plate coils. In one example, the flat plate coils 10 are supported on a bar 104 passing through sleeves 91, which can be extended as illustrated to maintain the plate coil spacing. Referring back to Figure 2, a flexible connection is incorporated between the plate coil inlet nozzles 20 and the inlet manifold 26, and a similar flexible connection is incorporated between the plate coil exit nozzles 22 and the outlet manifold 28. In Figures 21a and 21b, the ends of the bar 104 are supported by the casing of the bulk material heat exchanger 24. The lift means 106 for lifting and rapidly dropping the bar 104 and the flat plate coils 10 is attached to the bar. The lift means 106 would raise the bar 104 off of its supports 105 by a fraction of an inch, as illustrated in Figure 21a and then allowed to fall under the effect of gravity back onto the supports as illustrated in Figure 21b. By the lift means 106, the flat plate coils 10 supported by the bar 104 are raised and dropped resulting in developing a shock wave through the flat plate coil. The resultant shock wave will dislodge any present bulk material blockage between adjacent coils 10.

[0085] The lift means 106 could incorporate, for example a cam 108 that is driven by motor 110. The cam 108 is in contact with the cam follower 112 attached to the end 114 of the bar 104. The cam 108 can include a gradual lift profile about a predetermined number of degrees of rotation and a flat profile about a predetermined number of degrees of rotating. Figure 21c illustrates an example of a cam profile that could be used. The lift profile of the cam 108 will gently raise the support bar 104 and the plate coils 10 to a maximum predetermined lift that is a fraction of an inch. The flat profile 109 of the cam 108 will cause the bar 104 to free fall under the force of gravity the distance it was

originally raised causing the bar to impact its support 105, thereby forming a shock wave through the plate coils 10.

[0086] Referring to Figures 22a, 22b and 22c, an additional example of the lift means 106 is illustrated and will be described. A cam 116 for each plate coil 10 can be incorporated into the support bar 104 and a cam follower 118 can be incorporated into each sleeve 91. Upon rotation of the support bar 104, for example by attaching an end 114 of the support bar to the shaft of a motor, the plate coils 10 are raised and lowered based upon the profile of each cam 116. Preferably, the maximum lift of each cam 116 is sequentially offset so that each plate coil 10 will be raised and lowered in predetermined sequence thus creating a shearing effect in the material between each adjacent plate coil. Turning to Figure 22b, the cam profile of the cam 116 can include a steep profile section 120 which would cause the plate coil 10 to fall under the force of gravity a predetermined distance in accordance with the profile section 120. This fall would send a shock wave through the plate coil 10 and aid in the removal of the material from of the exterior surface thereof.

[0087] Figure 22c illustrates an additional example of a cam profile for the cam 116 that could be used. In this example, the plate coils would be raised and lowered in a predetermined sequence thus creating a shearing effect the material between each adjacent plate coil. The incorporation of a scraper element 122 into the bearing surface of the sleeve 91 would act to keep the surface of the cam 116 clear of material debris that could impede the operation of the cam.

[0088] Referring to Figure 23, which illustrates an example of a cam arrangement including an eccentric cam 116 and cam followers 118 incorporated into the sleeve 91 of a plate coil. In this example, upon rotation of the support bar 104 the cam followers 118 would follow the profile of the cam 116 and plate coil would translate horizontally back and forth. Such as described above a plurality of cams 116 would be incorporated along the

length the support bar 104 with the maximum lift of each cam 116 offset from each other to create a shearing effect in material between each adjacent plate coil.

[0089] Referring to Figure 24, which illustrates an additional cam arrangement example including a plurality of lateral cams 116 cut into the support bar 104 and a cam follower 118 incorporated into the sleeve 91 of each plate coil 10. In this example, upon rotation of the support bar 104 the cam follower 118 would follow the profile of the lateral cam 116 cut into the support bar 104 and the plate coils 10 would translate horizontally from side-to-side in unison. In addition, the sleeves are extended to provide spacing for adjacent plate coils 10. The side-to-side, unison movement of the plate coils 10 aids in dislodging bulk material accumulated between adjacent plate coils.

[0090] A method of automated cleaning of the exterior surfaces of adjacent plate coils is provided and includes the steps of providing at least two plate coils 10 arranged side-by-side in a spaced relationship, wherein the plate coils include a heat exchange medium inlet nozzle and an exit nozzle 20 and 22. Attaching the heat exchange medium inlet 20 and exit nozzles 22 to a heat exchange medium supply system 102, wherein the supply system includes a vacuum source which is attached to the heat exchange medium exit nozzles for creating a negative operating pressure within the plate coils. Isolating the vacuum source allowing the heat exchange medium to develop a predetermined desired hydrostatic pressure within the plate coils 10 to slightly inflate the plate coils to reduce the space between the plate coils and compress any bulk material that is accumulated on the exterior surfaces of the sides of the plate coils. And reconnecting the vacuum source to reestablish the negative operating pressure and thus deflating the plate coils 10 to increase the space between the coils and dislodge the compressed bulk material.

[0091] This method may also include connecting a pulsing 100 system between the vacuum source and the exit nozzles of the plate coils to isolate the vacuum source and reconnect the vacuum source in a cyclic manner having a predetermined frequency.

**[0092]** An additional method of automated cleaning of the exterior surfaces of adjacent plate coils is provided and includes the steps providing at least two plate coils 10 arranged side-by-side in a spaced relationship, wherein the plate coils are supported by a support bar 104 having the ends 107 thereof supported by supports 105. Attaching a lift means 106 for lifting the support bar 104 off of the supports 105 to the ends 107 of the support bar. Raising the support bar 104 and supported coils 10 by the lift means 106 a predetermined distance off of the supports 105. Dropping the support bar 104 under the force of gravity the predetermined raised distance onto the supports 105 to send a shock wave through the coils 10 to dislodge bulk material that has accumulated on the exterior surfaces of the coils.

**[0093]** An additional method of automated cleaning of the exterior surfaces of adjacent plate coils comprising is provided and includes the steps of providing at least two plate coils 10 arranged side-by-side in a spaced relationship, wherein each plate coil is supported on a cam 116 attached to a support bar 104 and wherein a support sleeve 91 of the plate coil includes a cam follower 118 which is in contact with the profile of the cam. And rotating the support bar 104 so that the cam follower 118 of sleeve 91 of each plate coil 10 follows the profile of the cam 116 which it is engaged so that the plate coil is raised and lowered in accordance with the profile of the cam so as to remove material that has accumulated on the exterior surfaces of the plate coil

**[0094]** Preferably in this method, the maximum lift of each cam 116 is offset by a predetermined number of degrees so that each plate coil 10 is raised and lowered in a predetermined sequential pattern so as to create a shearing effect of the material between the adjacent plate coils. Most preferably, the profile of the cam 116 includes a steep section 120 so that the plate coil 10 is caused to fall under the force of gravity a predetermined distance in accordance with the steep section of the cam profile so that a shock wave is sent through the plate coil to aid in the removal of the material. In

addition, the sleeve 91 of the plate coil 10 may include a scraper element 122 that would act to keep the surface of the cam 116 clear of material debris that could impede the operation of the cam.

**[0095]** While a preferred embodiment of the flat plate coil has been described in detail, it should be apparent that modifications and variations thereto are possible, all of which fall within the true spirit and scope of the invention. With respect to the above description then, it is to be realized that the optimum dimensional relationships for the parts of the invention, to include variations in size, materials, shape, form, function and manner of operation, assembly and use, are deemed readily apparent and obvious to one skilled in the art, and all equivalent relationships to those illustrated in the drawings and described in the specification are intended to be encompassed by the present invention.

**[0096]** Therefore, the foregoing is considered as illustrative only of the principles of the invention. Further, since numerous modifications and changes will readily occur to those skilled in the art, it is not desired to limit the invention to the exact construction and operation shown and described, and accordingly, all suitable modifications and equivalents may be resorted to, falling within the scope of the invention.